OPERATIONAL ASPECTS OF THE NRL MICROWAVE INTERCEPT SYSTEM

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ABSTRACT
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During a period of several months, the rapidly scanned
microwave intercept system developed by the Naval
Research Laboratory has been investigated with respect to
operating procedures, advantages, and limitations.
Although the basic characteristics and capabilities can be
determined by laboratory techniques, it is recognized that
operation with respect to live signals of various radiation
and operating characteristics is necessary for even a
limited evaluation of the potential of the equipment.

A part of this investigation was concerned with estab-
lishing the operating procedures to be used for the general
intercept problem and for special operations where intel-
ligence or collateral information or specific strategic need
effectively improves the operating capabilities.

The prime objective of the search for signal activity
was to intercept as many different signals of as many dif-
ferent radiation and operating characteristics as possible
and to correlate the resultant information with known
sources of transmissions. In spite of the relatively poor
location of the intercept site from the standpoint of the
surrounding terrain, a large number of signals were
intercepted.

As a result of this study, basic operating information,
system capability, and suggestions for improvements and
refinements of the system have become apparent.

PROBLEM STATUS

This is an interim report on one phase of two
problems, work is continuing.

AUTHORIZATION

OPERATIONAL ASPECTS OF THE NRL MICROWAVE INTERCEPT SYSTEM
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INTRODUCTION

The rapidly scanned microwave intercept system developed by the Naval Research Laboratory has been in operation for a relatively short time, but during this period considerable effort has been expended in investigating the operating procedures, advantages, and limitations associated with the system. Although this investigation has not been completed, it is evident that the present results should be made available to indicate the effectiveness of the system with respect to live signals and to guide further operational evaluation and technical development.

DESCRIPTION OF THE SYSTEM

Details of the intercept system have been reported previously (1-3), and a final system report is in preparation. A description of the installation is of value, however, to provide a background as to the validity and limitations of the investigation. The relative locations of the antennas, waveguide feeds, and coaxial and power cable runs with respect to the receiver-indicator-control console are shown in Fig. 1.

Antenna Group

The antenna, AN/SLA-3 (prototype of AS-605/SLR), provides a direction-finding capability for the system from 1000 to 10,750 megacycles. The antenna is capable of rotating at controlled speeds up to about 300 rpm or of being manually slewed to any azimuth position. Although the center of the antenna group is only 87 feet above sea level, it is essentially in the clear of the remaining structures at NRL as far as effective horizon is concerned. About the only near-by structure offering possible screening is the 50-foot radio telescope approximately 0.4 mile distant. Unfortunately, the effective horizon is restricted by rises in the terrain. Over an easterly sector of about 160 degrees, a nearby ridge increases the horizon angle to as much as plus five degrees. Throughout the remaining 200 degrees the horizon angle has a value averaging about plus one-half degree. Consequently, the performance of the system, with respect to range, is substantially degraded over somewhat more than a third of the azimuth circle. The effect of the local terrain is apparent in Fig. 2, which shows the radar horizon distance to a 1000-foot altitude.

RF Transmission System

Two waveguide runs, RG-109/U and RG-110/U, are used to couple the 2300 to 10,750 megacycle antennas to the operations room. These guides are about twenty-seven feet long and are terminated within the operations room by coaxial transitions. The transitions are connected to rf switches which in turn are connected by short lengths of RG-9A/U cable to the receiver tuning units. The rf switching is necessary since the two antennas must be shared by three tuning units. The antenna for the 1000 to 2600 megacycle region is connected to the appropriate tuning unit by means of about 33 feet of RG-9A/U cable.
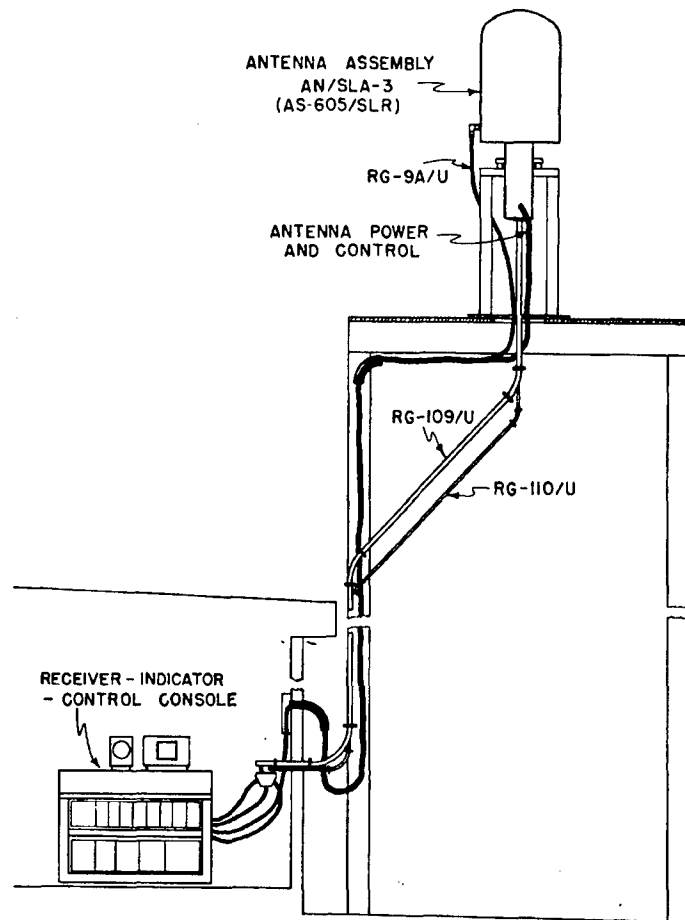
Fig. 1 - System installation, showing
major components and transmission lines

    The RG-9A/U coaxial cable attenuation is normally unaffected by climatic conditions. On the other hand it is recognized that the waveguide sections, particularly at the higher frequencies, could be subject to high losses caused by moisture within the guides. The radar designer has solved this problem by providing a pressurized dry air or gas system. The radome and drive system of the intercept antenna, however, are not capable of operating as a pressurized system in the present design. A scheme was devised that might be termed continuous dry-air flushing. Dry air is supplied to the smaller of the waveguides at the coaxial transition. The air then passes up through the guide to the antenna unit where it passes out of the guide into the antenna drive pedestal. From this latter space the air flows up into the radome, then down the larger guide to the operations room where it is exhausted through a silica gel indicator section into the room. The air flow volume is low with an input to output pressure differential maintained at a fraction of a pound per square inch. Occasional visual inspection and the operating results of the intercept equipment have indicated the effectiveness of this method in keeping the transmission efficiency near the maximum value.

Receiver-Indicator-Control Console

The operation of the intercept system is conducted from the console shown in Fig. 3. The acquisition indicator and the analysis (unified display) indicator are shown at the left and right, respectively, above the control section. The control panel consists of four basic units: (1) position-storage selection and indication, (2) receiver manual-tuning control, (3) receiver function controls, and (4) direction-finder antenna controls. It is advantageous to describe this portion of the system by introducing the operating functions in the sequence of use.

Acquisition Indicator - The initial purpose of the acquisition indicator is to provide a means for recognizing the presence of signal activity within the frequency limits of the tuning unit in use. This is accomplished by scanning the receiver in a symmetrical saw-tooth fashion over the frequency band of interest and presenting the resultant receiver signal output (suitably modified) in a raster display on a cathode-ray tube. In this presentation the horizontal position of the spot corresponds precisely to the receiver frequency at every moment in the tuning, the vertical position is a function of time and slowly drifts downward (recycling every two minutes), and the signal activity is represented by the intensity of the spot. Since a long-persistence phosphor (P-25) is used in the cathode-ray tube, a short history of signal activity is available to the operator. The photograph in Fig. 4 is an exposure of two minutes to show the nature of a developed raster with various signals. Actually the operator sees only the immediate spot with high brightness, the preceding traces of the raster being visible as a fading afterglow which is essentially gone by the time the sweep returns in the next vertical cycle. Figure 5 is a better representation of the actual appearance of the acquisition display at some instant.

The operator is thus equipped with a display that enables him to recognize the appearance of new signals in the presence of others. The display does not require continuous attention since the afterglow record provides a recall up to about two minutes. It should be mentioned that audio monitoring has proved to be a definite aid in the acquisition of signals.

Once a signal has been displayed, the acquisition indicator may be used for its second purpose. Whenever the operator decides to study a particular signal in detail, he switches the receiver from the scanning mode to manual-tuning by depressing one of the position-storage selection push-switches and then using the tuning control to place the cathode-ray tube spot in alignment with the afterglow of the signal under study. This operation sets the receiver on the frequency of the signal and energizes the analysis indicator.
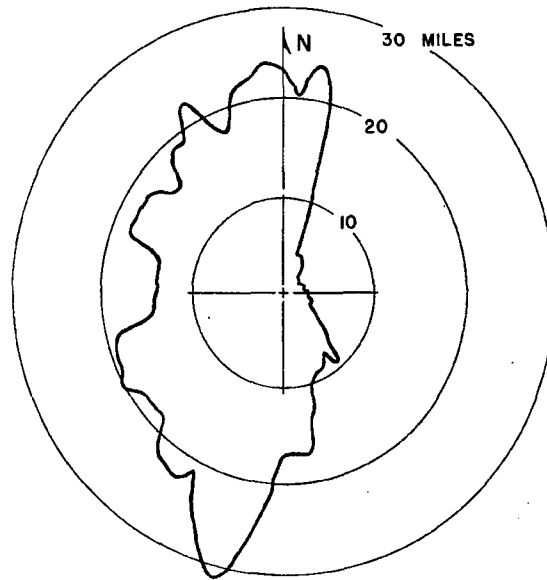

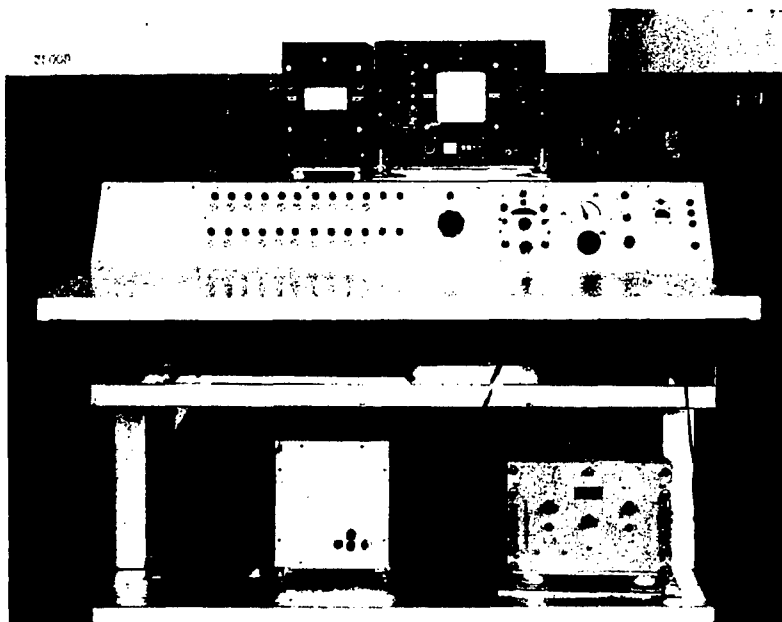Fig. 2 - Radar horizon distance from intercept site for a 1000-foot altitude

Fig. 3 - Receiver-indicator-control console
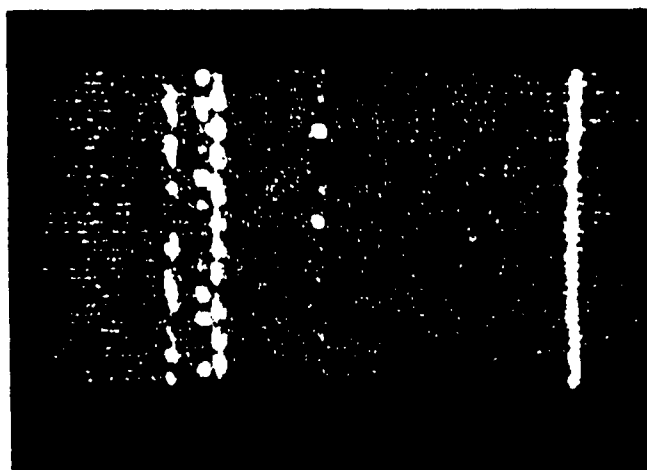
Fig. 4 - Two-minute exposure of the
raster display of signal activity

Fig. 5 - Instantaneous appearance of the
raster display, showing signal afterglow

Analysis Indicator - When a signal has been selected for study, the combined display
unit provides the means for determining the values and characteristics of the signal
parameters either by immediate visual observation or by later interpretation through
the use of photographic recording. The cathode-ray tube presents three calibrated time
bases, a calibrated direction-finder display, and a panscope trace simultaneously. Fig-
ure 6 shows the scales of a modified KD-2 camera associated with these five traces.
The display of a typical signal (a type AN/CPS-1 radar at Washington National Airport) is
shown in Fig. 7 to illustrate the presentation of information. The usefulness of calibrat-
ing the time bases in time only instead of a combination of time and repetition frequency
will be demonstrated in a later section.

Fig. 6 - Unified-data-display scale calibrations

Fig. 7 - Unified display of type AN/CPS-1 radar high beam
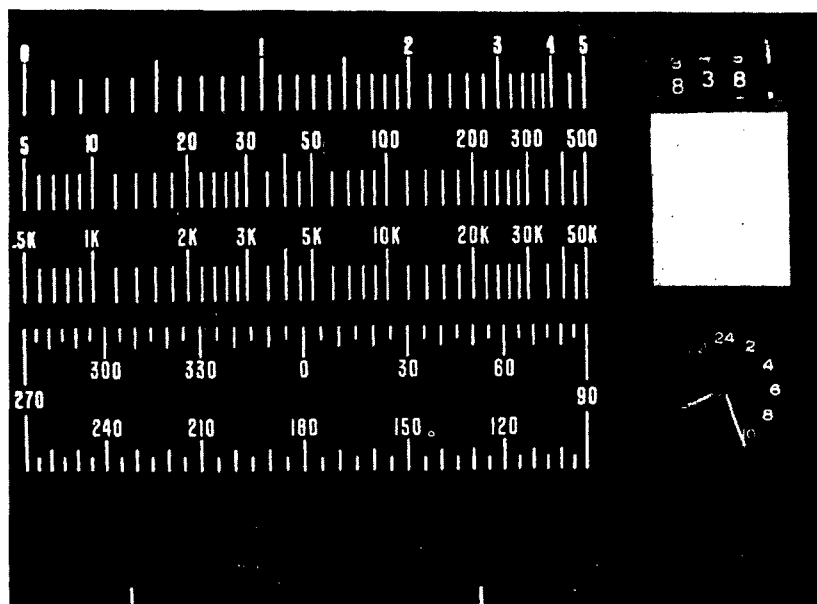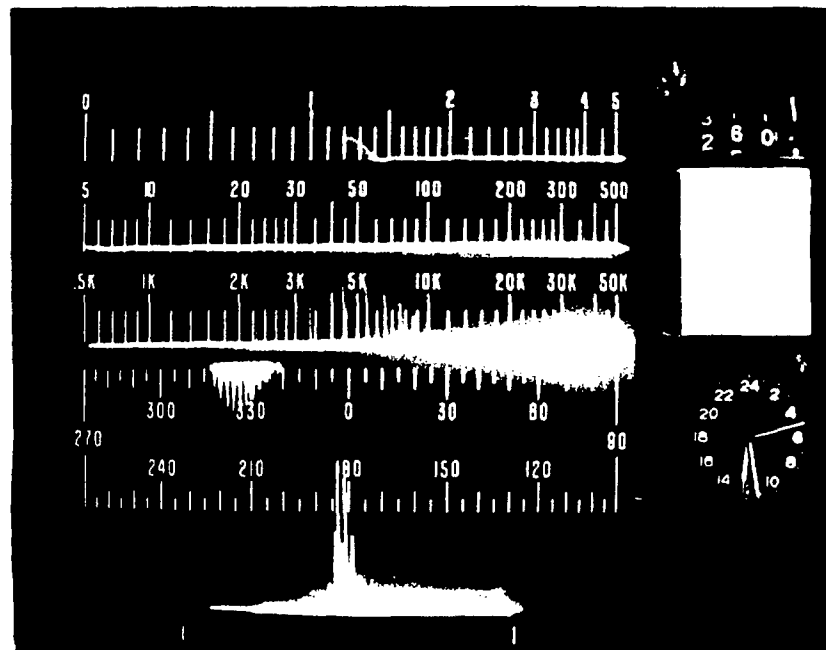(pulse width, 1 μsec; pulse period 1150 μsec; bearing 326°)

The analysis indicator also provides direct reading of the receiver frequency by means of a counter located below the face of the cathode-ray tube. As the receiver is switched from one tuning unit to another, this frequency indicator automatically aligns with the selected tuning unit without additional manipulation.

Position Storage - Whenever a position-storage selection push-switch is depressed, the receiver tuning unit in operation quickly tunes to the position represented by the particular store. At the same time, the potentiometer of the particular store is connected to the receiver manual-tuning control. Consequently the store may be changed to represent a different position, in which case the tuning unit seeks the new position as rapidly as the tuning control can be varied. It is possible, therefore, for the tuning unit to be tuned accurately and quickly to a number of positions limited only by the number of stores available.

As an aid to the operator, each position-store has two indicator lights. One of these lights is illuminated on the initial operation of the associated switch and stays on to indicate that the store has been selected and used. This light may be cancelled at any time by actuating an auxiliary push-switch simultaneously with the position-store switch. The second indicator light is on only when the particular store is in use, to provide a reference to the operator. The arrangement of the indicator lights provides for the former to show as position-store numbers (1, 2, 3, 4, etc.) and the latter as illuminated switch buttons.

Receiver Function Controls - This portion of the console is similar to the control panel of the AN/APR-9 receiver. The selection of the tuning unit for operation also selects the proper antenna or antennas for each unit. As in the AN/APR-9, sector limit controls enable the operator to select limited frequency bands within the tuning ranges. A combination gain control is provided to minimize manipulation when changing the mode of operation from acquisition to analysis and from analysis to acquisition.

The operator has control of using the receiver either in the wide- or narrow-band i-f modes. Normally, acquisition and analysis utilize the wide-band position. The superior frequency resolution provided by the narrow-band operation cannot be used for general search and analysis but is of substantial value when several signals are found within a narrow spectral region. To aid the operator in setting the receiver so that the signal of interest will be in the narrow-band limits, a fixed-oscillator function can be used.

For the convenience of the operator, the push-switch that changes the receiver from the analysis mode to the acquistion mode is located at the top of the panel.

Direction-Finder Antenna Control - Although the DF antenna is usually operated at the maximum speed of about 300 rpm, the operator can select lower speeds, as required. In addition, the operator can slew the antenna manually to any azimuth position whenever required. Since the inertia of the antenna prevents rapid slewing to position, a steering indicator has been provided to enable the operator to preset the azimuth position with reasonable accuracy. Selection of true or relative bearing information has been incorporated, since this feature is of importance for airborne and shipboard installations.

OPERATING PROCEDURE

General

As a result of experience gained in the use of the rapidly scanned system and theoretical investigations, a "normal" operating procedure has been developed. This "normal" procedure should not be construed as the only method, since it is understandable that other procedures may be of greater use for particular strategic and tactical operations. Some of the departures from the usual sequence will be mentioned in subsequent sections.

The search operation is started by switching in the tuning unit that covers the frequency spectrum of interest and setting the sector limit controls for full frequency scanning. This action is followed by setting the bandwidth switch in the wide position, switching the receiver to the scanning (acquisition) mode, and adjusting the DF antenna for maximum rotation speed. The operator then adjusts the receiver gain control to produce a slight noise background on the acquisition indicator, and sets the audio gain control to provide an audible noise background in the head set.

The operator proceeds to monitor the system for signal activity as evidenced by the appearance of intensified spots on the acquisition indicator scan that are correlated with audio responses. When the presence of a signal is indicated, the operator selects an inactive store by a push-switch. This action transfers the receiver from the scanning mode to the manual tuning mode so that the operator can set the receiver to the frequency of the indicated signal. As was mentioned previously, this is accomplished by tuning the receiver so as to align the indicator spot with the afterglow produced by the signal.

At this point the operator shifts his attention to the analysis indicator. The characteristics and relative spatial position of the signal determine which of the display functions will be observed first as well as the waiting time before the display. If the source of the signal is a normal type of radar within or slightly beyond the radar horizon, the waiting time for an indication is negligible. In this case the operator may tune the receiver slightly to place the signal spectrum in the center of the panscope trace for a more accurate determination of signal frequency. The next step would be observing the DF display while adjusting the receiver gain for the best presentation of the DF information as derived from the side- and back-lobe radiation from the radar. This operation would be followed by photographing

the display for recording all of the information or by visually observing the time base sweeps for determining the pulse width and pulse period.

When the signal source is beyond the effective radar horizon, the waiting time for an indication may be several seconds. Experience with the system indicated that under this condition the operator should primarily watch the DF display. As soon as an approximate bearing has been determined, the antenna is manually slewed to that bearing and the fixed-oscillator is turned on. With the next burst or bursts of the radar, the operator determines the pulse characteristics and tunes the receiver to align the signal with the narrow-band slot. The receiver is immediately switched to narrow-band operation, and the antenna is returned to azimuth scanning. The effective increase in sensitivity of narrow-band operation provides a more accurate determination of the signal's bearing. It should be pointed out that narrow-band operation would not have been used if the pulse analysis indicated a pulse width of less than one microsecond.

With the completion of the analysis, the operator resumes the acquisition mode by depressing the proper switch, checking to see that the various controls are in the correct mode for the scanning function. Whenever another signal is observed, an inactive store is selected and the preceding scheme of operation is repeated. The active store provides the operator with the means of quickly retuning the receiver to the previously acquired signals so that they may be monitored when required. Such monitoring may be for the purpose of noting any change in bearing or operating characteristics or to determine whether the signal source has receded beyond detection range or has terminated operation. Whenever a position-store is considered to be of no further use, it may be released from the active indication by simultaneously depressing the cancel switch and the position-store switch.

Special

There are many variations from the "normal" operating procedure previously described that are of value for particular conditions and operations. Any attempt to describe more than a few of these variations would be of little value except to an actual operator of the equipment. On the other hand, a brief description of some of the deviations is necessary to demonstrate the capabilities of the equipment.

Two alternative methods for the acquisition phase are immediately evident. One is the restriction of frequency sweep to a sector of interest with the consequent more rapid build-up of cumulative probability. The second is the steering of the antenna to the bearing of anticipated or suspected activity. This action provides an effective increase in sensitivity and a more rapid increase of the cumulative probability.

A third variation of importance requires that the receiver be operated in the narrow-band mode during the acquisition period. Although this type of operation provides improved resolution and an effective increase in sensitivity for many types of signals, it also results in a decreased capability for intercept of signals characterized by low repetition rates or pulse widths less than about one microsecond. When the preceding methods of limited sector scan and nonrotating antenna can be combined with the narrow-band operation, the capability of the system for long-range intercept can be exceeded at the present only by incorporating a larger antenna (in place of the AN/SLA-3) which may be steered precisely toward suspect sources of radiation.

When the system is switched to the analysis mode, the narrow-band function is especially useful when a multiplicity of signals exist within a relatively narrow spectral region. This

condition of operation provides increased frequency resolution and discrimination against undesired signals so that the signal of immediate interest may be effectively analyzed. It is not possible to provide a complete and accurate analysis when only narrow-band operation is used, because there is a degradation of information with respect to pulse width and shape. Experience with the system, however, has shown that it is possible to extract and correctly correlate information from both the wide and narrow conditions so as to provide accurate signal information, even though wide-band operation might display a number of different signals.

There are occasions when the DF antenna should be hand-slewed to the observed bearing of the signal source in order to provide certain information. This is the case when antenna scan characteristics such as rotation rate, sector sweep, or conical scan are to be obtained. As an example, the operator is able to determine the beamwidth of the radar antenna by slewing the DF antenna to the bearing of the signal. The receiver gain is then set to trigger the time bases near the peak of the main beam. The time to the first null can then be determined and compared to the rotation period of the antenna.

It has also been noted that whenever the radiating source is at extreme range, bearing information is difficult to achieve by continuous rotation of the DF antenna. Under these conditions, steering of the antenna for maximum response improves the accuracy of the information.

OPERATIONAL EXPERIENCE

During the period of operation of the system, a wide variety of signals have been intercepted and analyzed. These have included such signals as Air Defense radars, DME, FM data systems, IFF, air-traffic surveillance (CAA and military), antiaircraft-gun-site and Nike-site radars, pulse communication systems, commercial and military airborne radars, GCA radar at Washington National Airport, and a number of experimental and unidentified systems operating throughout the frequency spectrum from 1000 to 10,750 megacycles. It should be pointed out that the interception of the signals was initially accomplished through the use of the acquisition indicator with the receiver scanning in frequency and with the DF antenna scanning in azimuth. However, this is not intended to imply that each and every signal was resolved as an entity on the acquisition indicator. Quite often the indication of "a signal" on the acquisition indicator led to the determination of more than one signal. This was particularly true at X-band, where a number of aircraft may have radars operating within a few megacycles of one another.

1000 to 2600 Megacycle Band

The activity noted in the band of frequencies from 1000 to 2600 megacycles is mainly attributed to Air Defense radars operated by the Air Force and to radars operated by the 2d AA Regional Command of the Army. The range to these radars and the terrain between the radars and the intercept site limits the reception essentially to the main lobes of the radars. Terrain profiles to two sites in the Washington area that are consistently intercepted are shown in Figs. 8 and 9. Nevertheless, reception (acquisition) was normally accomplished within a few seconds after the initiation of the search period.

When the presence of a signal was determined on the acquisition indicator, the receiver was switched from the scanning mode so that the receiver could be tuned to the frequency at which the activity was noted. If a single signal was radiating, a determination of frequency, bearing, pulse width, pulse period, and pulse shape could be made within a few seconds. The accurate determination of antenna scan rate required additional time.
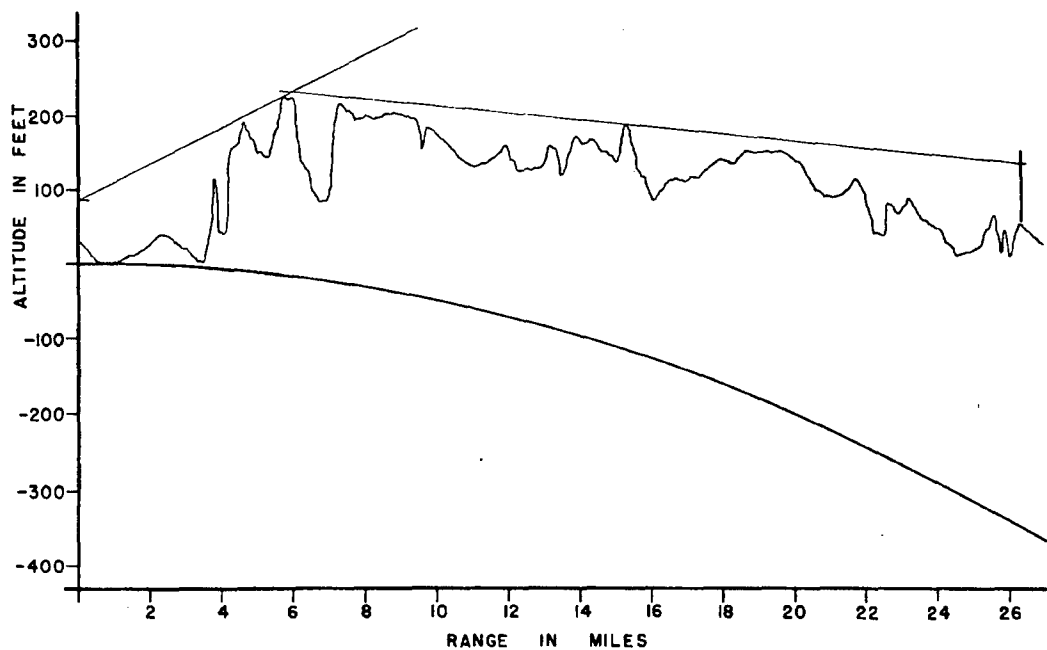
Fig. 8 - Terrain profile between intercept site
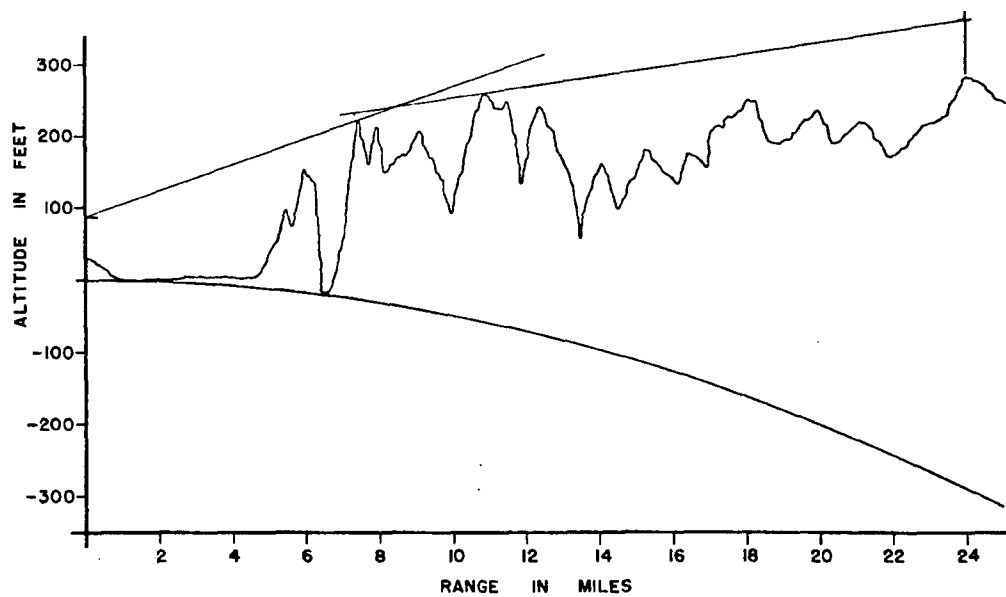and Air Defense radar southwest of Washington

Fig. 9 - Terrain profile between intercept site
and 2d AA Regional Command radars northwest of Washington

If more than one signal was present within the acceptance and display band of the receiver, it was possible to segregate the signals on the basis of operating frequency so that correlation of the signal frequency to the other parameters of the radar system could be obtained. Under such conditions it was determined that switching the receiver to narrow-band operation was of particular use in obtaining bearing information, since discrimination against the other radars was provided. This was particularly true when the bearings to two or more radars were within three or four degrees of each other.

The analysis display also made it possible to ascertain whether two transmitted frequencies were using the same modulator and/or the same antenna pedestal, even though the beams may be coincident or displaced in space with respect to each other.

The DME at Washington National Airport was another usual source of radiation. Because of its proximity to the intercept site and its nonrotating radiation characteristics, the DME was indicated on the acquisition indicator at every crossing of the frequency by the receiver. When the receiver was tuned to the DME, the analysis display provided information as to the pulse coding for identification and the replies upon interrogation as well as the usual pulse width, pulse period, and bearing indications (Fig. 10).
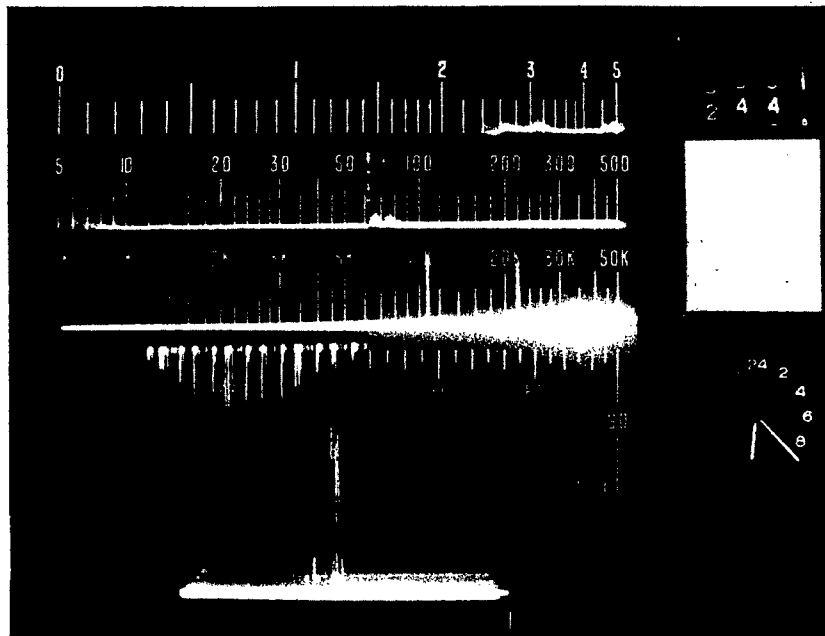
Fig. 10 - Unified display of DME radar

Airborne interrogations of the DME have been intercepted. On a number of occasions two or more such signals have been observed operating at the same time on frequencies within the narrow band of the receiver. These signals have been segregated successfully on the basis of the DF information.

An FM signal of unknown source or purpose has been consistently intercepted in this frequency region. The bearing and frequency deviation have been determined but no information of a varying character has been observed. Since no extended watch period has been

maintained with respect to this signal, it may be that the duty rate of information transmission is low.

2300 to 4450 Megacycle Band

The most regular signals in this band are the air traffic surveillance radars located at Washington National Airport. These radars consist of a two-frequency, antennas back-to-back, long-range search unit (AN/CPS-1), and a shorter range precision unit (ASR-3). Because of the short ranges to these radars from the intercept site, the field strength is always well above the minimum detection level of the receiver regardless of the position of either the radar antennas or the intercept antenna. Consequently, whenever the receiver scans through the frequencies of these radars, there is an indication on the acquisition unit. Actually, when the AN/CPS-1 radar antenna is illuminating the intercept antenna, there is sufficient energy in the side bands beyond the first few nulls in the spectrum pattern to be detected by the receiver. This results in a spreading or smear on the acquisition display whenever the receiver is scanning near the radar frequency at the time when the radar antenna is illuminating the receiving antenna. This effect can mask the transmission of signals of reduced levels that are within a few megacycles of a relatively high strength signal. Operating experience with the equipment minimizes the possibility of interpreting an indication as side-band splatter rather than another signal.

This situation is reproduced locally where a radar at Andrews Air Force Base is bracketed in frequency by the AN/CPS-1 and ASR-3 at Washington National Airport. A typical frequency distribution for these radars is: ASR-3, 2760; Andrews AFB, 2794; AN/CPS-1, high-angle beam 2865, and low-angle beam 2918 megacycles. The field strength, at the receiver antenna, produced by the Andrews AFB set is about 65 to 80 db below that of the airport equipments because of the loss due to intervening terrain (Fig. 11). Also, whereas the airport radars provide an effectively continuous illumination of the intercept antenna, the effective time of the Andrews AFB set is about 40 milliseconds. In spite of these factors, the signal from Andrews is presented on the indicator a few times in each two-minute raster and can be resolved as a distinct signal.

As has been indicated previously, the narrow-band capability of the intercept system is an aid in providing bearing information; in this case, the additional frequency discrimination provided against the airport radars enabled accurate information to be obtained quickly.

A number of signals of irregular operating habits have been observed at various times. The majority of these signals undoubtedly are associated with the 2d AA Regional Command gun and Nike sites, since bearing information points toward known positions of these operations. It should be pointed out that most of the bearing information obtained by the intercept system was noted before the actual positions were made known to NRL. Some of the bearings proved to be accurate within two to three degrees. With respect to these sites, it should be noted that most of them are below radar line of sight as far as the intercept position is concerned; consequently the radiation propagation is affected by diffraction phenomena.

A few additional signals have been found that are obviously experimental systems operating within NRL. But a number of others have not been identified, either because the signal parameters or the bearing information cannot be correlated with known equipment positions. It is recognized that other organizations within the Washington area may have experimental systems in operation from time to time, and it may be that these and other systems will be identified by future work.
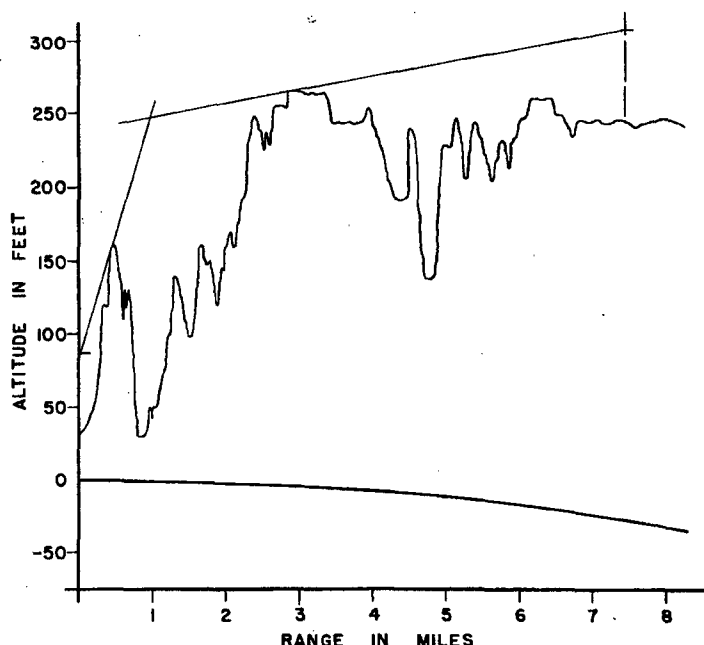
Fig. 11 - Terrain profile between intercept site
and Andrews AFB radar

4300 to 7350 Megacycle Band

With the exception of two signals, the activity noted in this band has been entirely air-
borne. One of these two signals is apparently a ground-based radar not too distant from
the intercept site, and the other is a pulse communication system. It has been estimated
that the intercept position is about four miles distant from the communication-system
transmitter and about 35 to 40 degrees off the axis of the transmission path. Although
this system was intercepted with the receiver operated in the wide-band mode, the parameters
of the pulse scheme could be determined only with the receiver switched to narrow-band
operation.

The many airborne signals at C-band have provided interesting information concerning
the use and effectiveness of the intercept system with respect to such sources. Radar-
equipped aircraft have been tracked (in bearing) on runs that have originated and terminated
at Washington National Airport, on runs that have bypassed Washington on the north-south
passage (Red 33 Airway), and on runs that were probably never within a hundred miles of the
Washington area. Those flights that passed within the Washington control zone could be
identified with respect to airline and flight number by monitoring the airway communication
frequencies. Unfortunately, no such simple procedure is available to specifically determine
flight paths and identification of those aircraft that are western traffic to and from New York
(Airways Red 8, Green 3, and possibly Green 4).

The intercept of airborne equipment either inbound or outbound to the northeast of
Washington is severely limited by the rising terrain near the intercept site. Figure 12
shows the effective radar horizons for aircraft at 10,000 and 20,000 feet. The signals from
outbound aircraft are very rapidly attenuated below detection level and inbound aircraft often
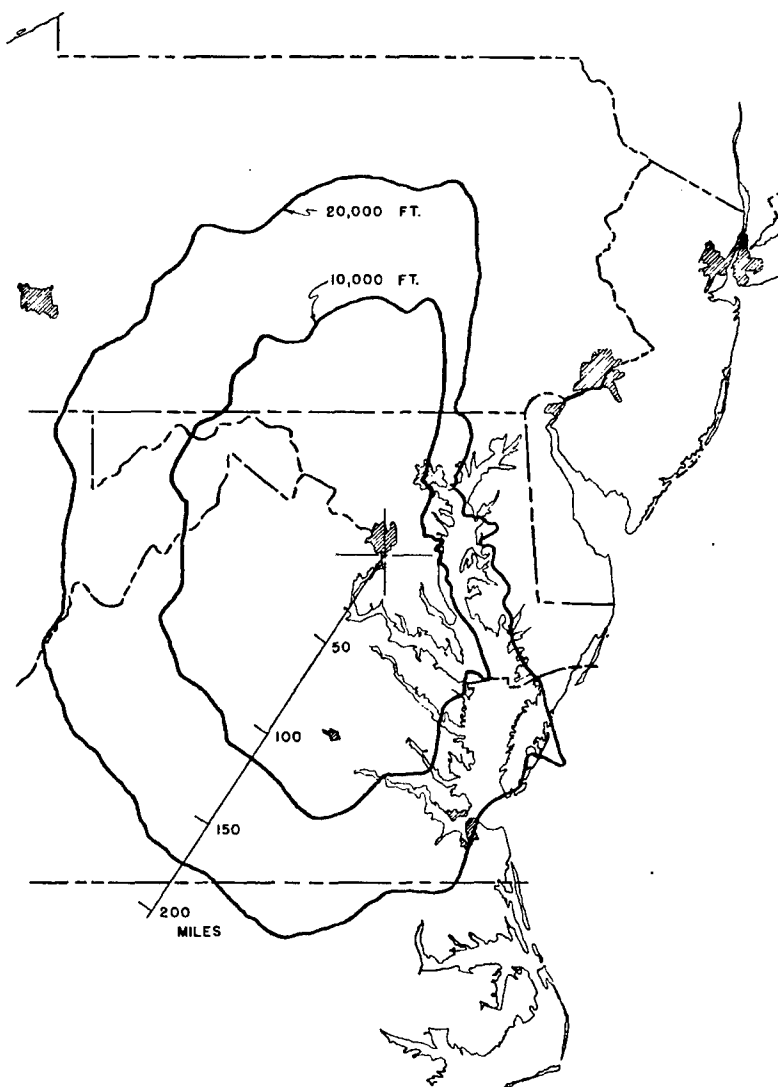
Fig. 12 - Effective radar horizons for altitudes of
10,000 and 20,000 feet

appear as having energized the equipment when within about ten minutes of the airport. Aircraft to and from Washington in the southwest quadrant, by contrast, have been held under observation for periods of about 30 to 45 minutes.

The greatest number of C-band signals have been those within a northerly sector from about 310 degrees to 15 degrees true, that have not had Washington either as the point of arrival or departure. Signals passing through this sector have been tracked for periods in excess of 30 minutes. On one occasion four aircraft (two headed east and two west) with radar frequencies within a twenty-megacycle band were observed in this sector during the same twenty-minute period. The narrow-band function of the receiver was used to

establish the initial relation of frequency and bearing. Thereafter, the wide-band oper-
ation was capable of providing an essentially continuous and unambiguous presentation
of the moving traffic except during the short periods when the oppositely headed aircraft
passed at the same bearing.

Attempts were made on the basis of time-bearing information to approximate the flight
paths of two different types of aircraft. Since the identity of aircraft type was not known,
two airspeeds were assumed and the tracks computed. For a speed of 360 mph (DC-7),
the track proved to be close to Airway Red 8 (across Pennsylvania about two-thirds of the
way from the south-to-north state boundaries); and for a speed of 300 mph (DC-6), the track
approximated Airway Green 3 (about the middle of Pennsylvania). It is anticipated that
future time-bearing information might be correlated with flight information from other
sources such as Air Traffic Control of the CAA. The obvious purpose of such a correlation
would be to establish the altitude-range capability of the intercept system.

7050 to 10,750 Megacycle Band

As would be expected the majority of signals in this band were from airborne equip-
ments. Among this group were military and commercial units. But whereas the parameters
of the radar systems at C-band did not show an appreciable variation, the systems at X-band
provided a wide variety. Some systems were noted that changed pulse width and/or pulse
period at intervals, others had jittered pulse periods, still others were equipped with
conically-scanned antennas, and a few even changed operating frequencies.

Generally, bearing and other analysis information were easily obtained. About the
only difficulty existed when aircraft at a considerable distance were operating at frequencies
within five to ten megacycles of radars in aircraft parked at Bolling AFB (about one mile
from the intercept site). This condition was aggravated when the distant radars were oper-
ating with pulse widths of the order of 0.1 to 0.3 microsecond. In these circumstances the
narrow-band function was of little value in providing frequency discrimination since the
narrow pulse is attenuated by 10 to 30 db.

As with the operation in C-band, there was often more than one signal within a twenty-
megacycle portion of the band. On one occasion a flight of three aircraft with frequencies
within a band of less than ten megacycles was resolved and tracked. At another time two
aircraft were observed on frequencies about seven megacycles apart and were obviously
approaching the intercept position from the south and were not on appreciably different
bearings. The angle between the radars was then observed to be increasing, slowly at
first and then rapidly, indicating there was a range separation between them. The signals
were observed to pass through the 270-degree bearing with about 30 seconds of time dif-
ference. The aircraft were visually observed to be on final approaches, one to National
Airport and the other to Bolling AFB.

In addition to airborne radars, a number of other signals have been intercepted. The
precision approach radar at National Airport is used as a reference signal. Some of the
other signals have been identified with antiaircraft-gun sites. A number of others, such
as a square-wave modulated signal used in antenna pattern plotting, have had their origin
within NRL. A few others have not been identified. Of these, some have been observed
only once or twice, and others have been intercepted a number of times. No attempt has
been made to positively identify each and every signal, since such an effort is beyond the
intent of this phase of investigation.

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Supplementary Observations

During the course of the investigations certain observations were made, and a number of supplementary ideas that should be considered somewhat apart from the preceding sections were examined. Nevertheless, these items should be included since they provide a fuller picture of the equipment capability.

Throughout the operational study of the system, a log of the signals intercepted was maintained with particular reference to those signals of apparent fixed locations. This log was for two major purposes; first, to serve as a reference for future observations, and second, to provide a measure of the bearing accuracy and system capability when matched to collateral information of the locations of radar operating sites. When the site information was made available by the Army and the Air Force, a comparison with the signal log data indicated that many of the radar sites within 25 miles of the intercept station had been located with a bearing error not greater than two to three degrees. The log showed, in addition, a number of signals that could not be correlated with the site information and, in particular, an excess of L-band sources with respect to the Washington area.

Further study of the intercept data of two of these L-band signals and site information indicates that two Air Defense sites beyond 150 miles (one to the north and the other to the south) have been intercepted with bearing errors of less than two degrees. Since these signals have been intercepted a relatively small number of times and an examination of Fig. 12 shows that to the north and south the effective radar horizon for 150 miles is at an altitude of approximately 15,000 feet, it is reasonable to attribute these interceptions to anomalous propagation.

A second aspect of interest involved the direct substitution of a crystal-video receiver for the superheterodyne unit within the system. This substitution provided the crystal-video unit with the antenna and analysis indicator of the rapidly scanned system. Consequently an effective comparison between these two basic receiver techniques can be obtained. In particular, the experiment was aimed at the frequency region where the surveillance radars of Washington National Airport and Andrews AFB are grouped in a band of less than 200 megacycles. As was noted previously, a typical distribution of operating frequencies for these equipments is: ASR-3 (Washington), 2760; Andrews, 2794; AN/CPS-1 high beam (Washington), 2865; AN/CPS-1 low beam (Washington), 2918 megacycles. It is also recalled that the Andrews radar is 65 to 80 db below the Washington sets.

With the crystal-video receiver in the system, the Washington radars were readily detected, DF bearings established, and pulse characteristics determined. However, since the AN/CPS-1 uses a common modulator and a common antenna pedestal for both beams, the determination that two beams of different frequencies exist poses a problem to the intercept operator. It was found that by judicious use of the receiver attenuator the operator might correctly decide that two beams of a certain rotation rate existed rather than a single beam at twice the rotation rate.

The Andrews radar, on the other hand, was never detected by the crystal-video receiver. The first effort toward intercepting the Andrews set was with the DF antenna rotating and with the operator concentrating on the DF display at the known bearing while listening for the distinctively different repetition rate. This procedure was unsuccessful, so the antenna was slewed to the proper bearing and the display was observed while listening for the particular radar. At no time was there any indication of the presence of the Andrews equipment. It is obvious that there would be considerable masking of the low-level

signal by the local radars; yet it must be concluded that the signal level from Andrews was never high enough to be detected. If it is argued that masking prevented interception of the signal and that channelized receivers would solve the problem, then it is apparent that for this practical case the channel bandwidths would have to be somewhat less than one percent of the channel center frequency.

When the superheterodyne unit was placed back in the system and the normal procedure started, the acquisition indicator displayed the local signals as three separate transmitters on the first scan and indicated the Andrews signal three times during the first two minutes of operation. When the system was switched to the analysis function, the operating frequencies, pulse characteristics, and bearing information could be determined for all of the radar transmitters.

CONCLUSIONS

The experience gained from the operation of the rapidly scanned system has shown that a well-trained operator can rapidly intercept signals of widely different radiation characteristics and obtain accurate, unambiguous information concerning the signal parameters as well as the azimuth bearings. The system provides this information either for immediate tactical use (through visual inspection and interpretation) or for detailed strategic study (through photographic recording as well as visual observation). In addition, the system provides the means for rapid resetting of the receiver to selected signal frequencies for further analysis, comparison, or correlation.

The rapidly scanned system is capable of intercepting and analyzing pulse transmissions (radar and communication) that are beyond the range and ability of crystal-video receivers with comparable antennas and indicators.

The over-all capability and efficiency of the system could be improved by incorporating a few changes and additions. One of these changes is not a function of system but concerns antenna design. Repeated observations of the display and the ability to interpret the DF presentation indicate that the beamwidth associated with the S-band antenna provides the quickest and most reliable bearing information. The beamwidth of this antenna is from eight to twelve degrees at the three-db points. By contrast, the lower frequency antenna pattern is considered to be too broad (16 to 30 degrees) and the high frequency antenna pattern is too narrow (four to six degrees).

Two ideas should be incorporated to improve resolution in the acquisition indicator when a narrow frequency sector is being examined. First, the full width of the presentation display should be attainable in sector operation with the corresponding increase in optical resolution of signal activity. Second, a reduced scanning speed should be available when the receiver is scanned in the narrow-band mode. These two additions would provide the operator with the capability of relatively high resolution in those bands of frequencies where high signal densities are normally found.

Although experience has shown the value of the KD-2 camera as a means for rapidly recording the information on the analysis display, experimental efforts with motion picture photography using Tri-X film and recent processing techniques conclusively demonstrate that this latter photographic method is preferable. Two important advantages obtained by this method are: (1) less effort is required by the operator to produce acceptable and useful results, and (2) a more complete presentation of the signal, by virtue of the dynamic capability of a continuous record, is available for study.

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REFERENCES

1. Wald, B., "Rapid Scanning Techniques for Countermeasures Receivers," NRL Report 4410 (Confidential), September 1954

2. Markell, J. H., "Servo Systems for Rapidly Scanned Countermeasures Receivers," NRL Report 4510 (Confidential), March 1955

3. Hendrickson, A. H., "A Unified Display for Countermeasures Receivers," NRL Report 4585 (Confidential), August 1955

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